Radiochemical Diagnostics of Fission and Fusion Neutrons using Gold Detectors

Shannon T. Cowell and Anna C. Hayes, T-16

Nuclear tests at the Nevada Test Site used a suite of radiochemical detectors that were strategically loaded so as to permit integral performance diagnostics. Many of these detectors were chosen to optimize the monitoring of thermonuclear burn by counting the production of 14 MeV neutrons from fusion. Gold (^{197}Au) is one of the very important detectors and the transmutation of ^{197}Au to the unstable gold isotopes can be used to determine key information on yields, the shape of the neutron fluence, and the interplay between neutronics and hydrodynamics.

In this work we developed a radiochemical network to calculate the production of all the unstable isotopes of gold from ^{193}Au to ^{199}Au. The network allows for arbitrary neutron fluence exposures and neutron flux shapes. Sensitivity studies were performed to examine the effect of the nuclear physics uncertainties on the production of the unstable gold isotopes.

The (n,2n) reaction is a threshold reaction requiring high energy neutrons (E> 5 MeV), and is thus predominantly sensitive to the fusion neutrons. In particular, the two-stage reaction ^{197}Au (n,2n)^{196}Au(n,2n)^{195}Au plays a key role in determining the number of fusion reactions that take place during the course of a nuclear explosion.

Figure 1 summarizes our reactions network. We note that there are several nuclear isomers involved and their contributions cannot be neglected. At present there is only preliminary data available for some of these isomers and theoretical calculations of their cross sections have not been explicitly performed. In addition, there are conflicting cross sections available for one of the most relevant (n,2n) reactions, ^{196}Au(n,2n)^{195}Au. In particular, the Lawrence Livermore National Laboratory evaluated cross section at 14 MeV is 2.09 b, while the value used in radiochemistry at Los Alamos is 2.425 b. Figure 2 shows the effect of this uncertainty on the $^{195/196}$Au ratio. The ^{197}Au(n,3n)^{195}Au reaction has a threshold of 14.8 MeV and is thus primarily sensitive to up-scattered 14 MeV neutrons. The Los Alamos ENDF and Livermore ENDL cross-section libraries have significantly different predictions for this reaction and these differences can affect the $^{195/196}$Au ratio. Using the TD-weighting function, which has a non-negligible neutron flux between 15 and 17 MeV, we find that the ENDF and ENDL libraries show significantly different predictions for $^{195/196}$Au, (see Fig. 3).

For more information contact Shannon T. Cowell at scowell@lanl.gov.

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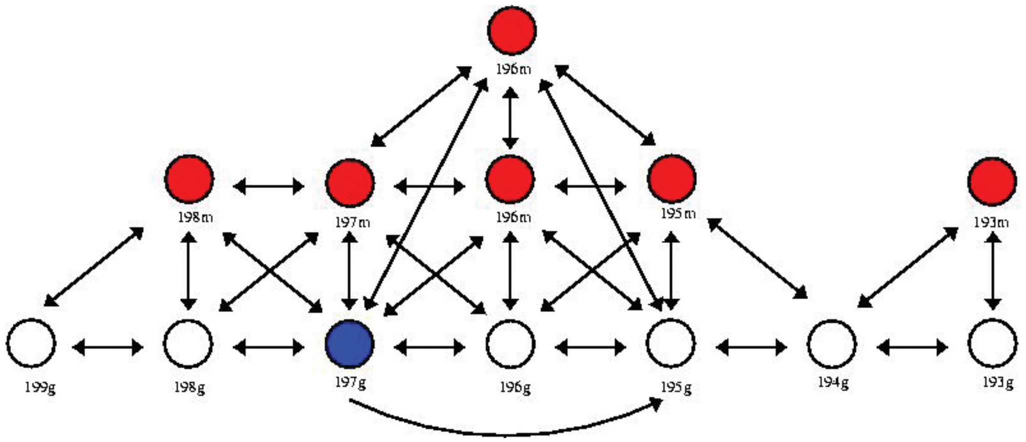

Fig. 1.
Gold radiochemical network (simplified).

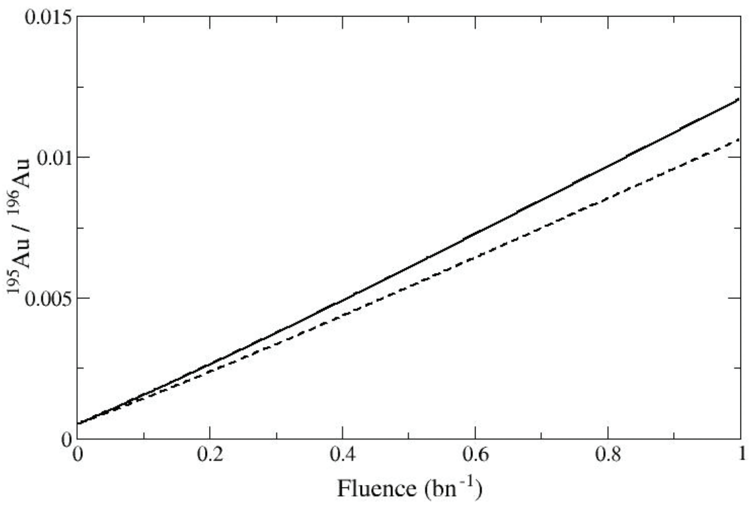

Fig. 2.
Comparison of $^{195/196}$Au ratio calculated using different available ^{196}Au(n,2n)^{195}Au cross sections.

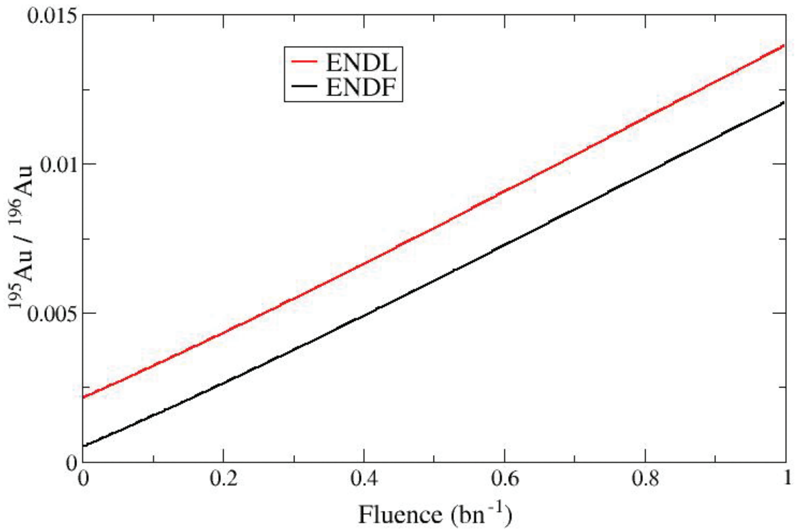

Fig. 3.
Comparison of $^{195/196}$Au ratio calculated using ENDL and ENDF cross-section libraries.